

## Filtration of Injection Water used for Enhanced Oil Recovery

### Introduction

Waterflooding, or secondary recovery, has long been an effective means of recovering oil from mature production formations. Commonly used after the original formation pressures have dissipated, water flooding can provide up to 30-40% additional production and is often used to maximize oil recovery. Effective oil recovery from waterflood operations requires an injection water filtration system capable of reducing well formation plugging particles. Failure to filter out these particles will reduce oil production, increase the frequency of injection well workovers, and, in the worst case, cause injection water pressure to increase to the point of fracturing the formation.

This Customer Application Brief (CAB) addresses the benefits of effective injection water filtration, both at the central distribution point and the point of injection, and the impact it has on reducing workover costs and increasing production.

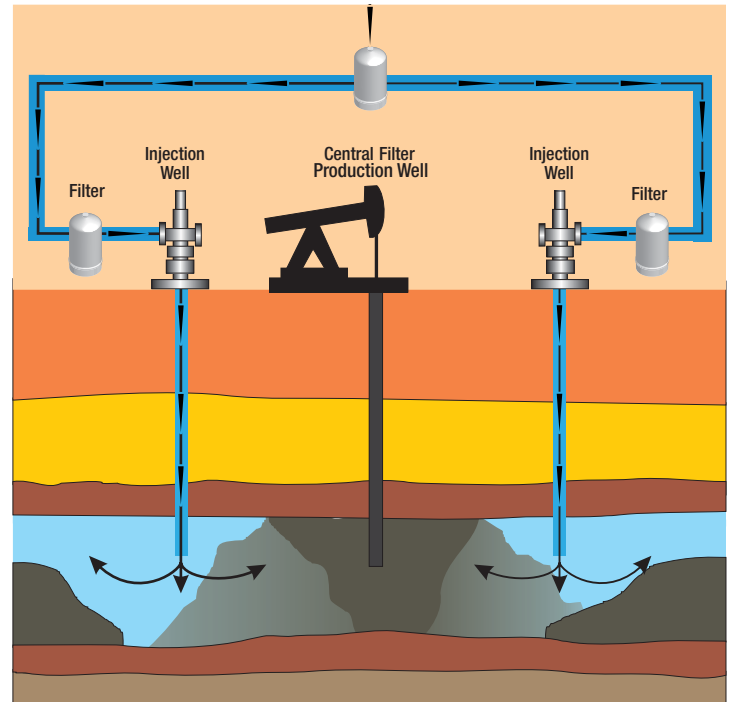


Figure 1 — Injection Wells

### The Process

Oil production from an oil-producing field will decline, over time, as the pressure of the producing formation dissipates. The operator of the field can compensate for this pressure loss by injecting water into the reservoir. In a waterflood operation, water from a central system is distributed to injection wells that surround a production well (Figure 1). Prior to being injected into the oil-bearing reservoir, the water is pressurized by high-pressure pumps such that it can penetrate the microporous formation. The water entering the well under pressure forces some of the oil that remains in the formation toward the production wells where it is brought to the surface.

### The Problem

Particulate invasion into the well formation due to contaminated injection water is a common problem. Because the formation pore size in the oil reservoir is typically very small, while the volume of fluid injected is proportionally large (10 to 100 thousand barrels per day), even relatively low levels of solids in the injection water (0.1-1mg/l) can have a significant impact on production levels and operating costs.

The nature of particulate in injection water varies due to many factors, including the type of water injected (source, seawater, or produced), geography, season, water temperature and depth from which it is extracted. Contaminants often include sand, colloidal iron, clays, and bacteria. These types of contaminants vary in particle size but can be as small as 0.5  $\mu\text{m}$ . Typical bulk water treatment such as sand filters, separators, strainers and chemical additions are limited in their effectiveness in protecting

the formation from these fine contaminants resulting in the need for cartridge filtration.

The most common problems include:

- **Perforation plugging** – solids become trapped in the casing or wellbore liner holes decreasing permeability and resulting in the injection of less water into the formation. Lower injection rates reduce the amount of oil produced. To maintain water injection levels, operators will increase the water injection pressure. This causes higher energy costs and increases the risk of well fracture. If allowed to continue, perforation plugging will result in reduced access to trapped oil, requiring more frequent well work-overs and acidizing.
- **Formation invasion** – particles invading the formation can bridge across the small pores of the internal formation (Figure 2) permanently denying access to the oil. Since the plugging takes place in the depth of the formation, workovers will not reverse this type of formation damage. The result is a reduction in the amount of oil ultimately produced by the reservoir.
- **Narrowed well bore** – the particulate forms a filter cake on the surface of the well bore resulting in lower injection rates and reduced production.
- **Well bore fill up** – solids settle to the bottom of the well by gravity and decrease the net zone height again resulting in reduced water injection and a changing of the profile of the flood and the need for costly work-overs.

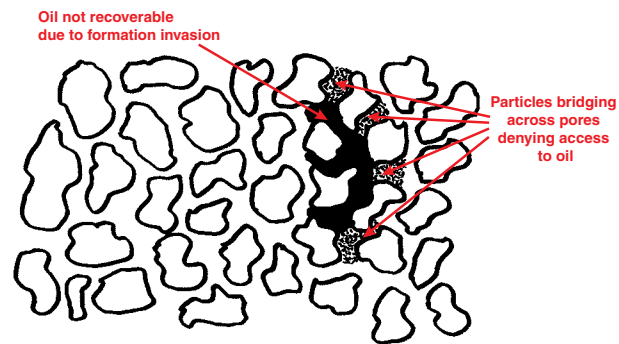


Figure 2 — Formation Invasion

When designing a filtration system for waterflood operations, the required level of filtration is usually based on core studies. Formation samples are taken and the expected water source is filtered to different levels, injected into the core and the impact on pressure build up, flow, and permeability/porosity is measured. In addition to core studies, the industry may use the following “rule-of-thumb”. The square root of the formation’s permeability approximates the mean pore throat diameter in the formation. Particles that are one-third the size of the mean pore throat diameter and larger can invade the formation and bridge across the pore throat. This “1/3” guideline is the level of filtration required to ensure proper formation protection. Example: A formation with a 100 millidarcy permeability requires injection water filtered to 3.3 micron ( $\sqrt{100} \cdot 1/3$ ).

## The Solution

3M Purification Inc. recommends the use of cartridge filtration at both the central system and the injection well heads. The bulk of the required filtration should be accomplished at the central system, where the filter housings of low pressure design are accessible, providing easy change-out. With the central system filtering particulate to the level indicated by the formation’s permeability making use of the 1/3 guideline, well head filters will only be required for contaminants generated as the water flows to the wellhead (pipe corrosion, scale, etc.). This provides the greatest filter life at the well head, significantly reducing change-out frequency, labor, and disposal costs.

### Filtration at the Central System

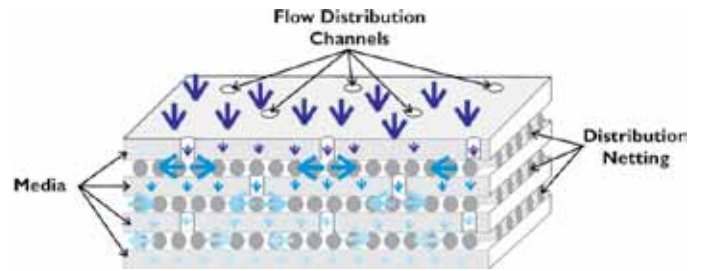
For systems where smaller diameter cartridges are preferred, the use of Betapure™ NT-T filter at the central system provide reliable and cost effective particle reduction. Betapure NT-T filter cartridges are 3M Purification’s latest advance in depth filtration technology. The all-polypropylene filter is constructed using a design that uses flow enhancing filter media and an innovative flow pattern. The result is an absolute-rated filter, available in ratings from 0.5  $\mu\text{m}$  to 70  $\mu\text{m}$ , with vastly superior on-stream life that provides more cost effective filtration than conventional filter technologies.

Betapure NT-T filter construction combines a unique polypropylene filter media with fluid distribution netting to form multiple layers. Critically positioned media flow channels allow greater movement of fluid from layer to layer. Three distinct media



Figure 3 — Three Distinct Layers

sections, made from multiple media/netting layers, are combined to form a filter cartridge (Figure 3). The outer and middle sections contain multiple layers of interleaved filter media and fluid distribution netting (Figure 4). Within each media layer, a portion of the fluid travels through the media while the balance of fluid is delivered directly to the next distribution layer through the flow channels. The fluid distribution netting provides longitudinal and latitudinal flow paths to evenly distribute fluid flow across the surface of each successive filter media layer. The inner-most layers of media, equal to one third of the filter's depth, are supported by a rigid polypropylene core. They contain no flow channels and constitute the final qualifying section providing absolute rated performance.



**Figure 4 — Unique Flow Pattern**

***Betapure™ NT-T Filter Advantages***

- Superior Service Life - as much as 4 times greater dirt holding capacity than competitive filters
- All polypropylene depth filter cartridges for broad chemical and temperature compatibility
- Ratings from 0.5 - 70 µm to suit a wide range of applications
- Absolute-Rated Performance for consistent filtration quality
- Exhibits superior particle retention under increasing differential pressure

Although the degree of filtration required will be determined by the formation's permeability, making use of the 1/3 guideline, typically 10 µm filtration is recommended.

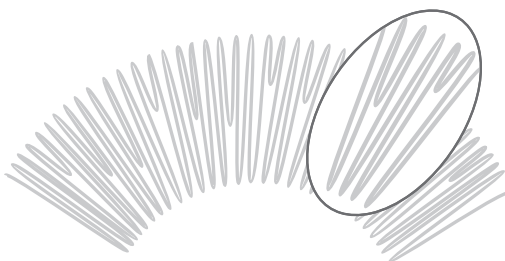
***Filtration at the Well Head***

The use of Betafine™ XL series filters (Figure 5) at the wellhead provides a final filtration step that will reduce contaminant generated as the water is distributed to the wellhead ensuring that the well formations are protected. The Betafine™ XL Series filter represents a major advance in pleated filter technology. This absolute-rated, 100% polypropylene, pleated cartridge features an Advanced Pleat Technology (APT) that increases the accessible filtration surface area while maintaining standard industrial cartridge dimensions. The result is a filter cartridge that provides predictable absolute rated performance while dramatically reducing total filtration costs. 2 µm filtration is recommended at the wellhead.

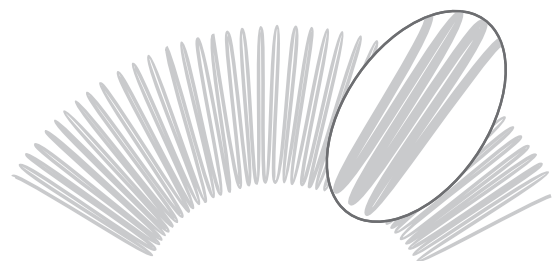


**Figure 5 — Betafine™ XL Series Filters**

The use of 3M Purification filter cartridges at both the central system and injection wellheads help maximize oil production while minimizing costly well workovers.



Betafine™ XL Series Filters Advanced Pleat Technology utilizes a unique configuration to increase the accessible surface area for significantly greater filter media use.



Conventional pleat designs, with full-depth densely packed pleats, fill the upstream pleat surface with contaminant that quickly constrict flow at the pleat's inside diameter.

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